Chapter 7
Data Analysis and Reporting

This chapter explains how data discussed in the previous three chapters will be analyzed and the results reported to park staff, resource managers, and policymakers. We have divided data analysis into three components: (i) descriptive analysis; (ii) trend analysis; and (iii) linking analyses to decisionmaking. Reporting describes the mode and frequency of delivery for providing this information to the relevant audience.

7.1 Data Analysis

The method of data analysis is intimately linked to spatial and temporal aspects of the sampling design that produced the data. Spatial inferences are clearly dictated by the sampling unit size and mode of selection, but additional decisions are required during the analytic stage regarding minimum resolution of inference. Combining sampled units into a single, parkwide (average) estimate of trend may obscure area-specific trends within a park. For instance, there may be a strong positive trend in a vital sign metric in the northern half of a park, but a strong negative trend in the southern half, which may essentially cancel one another when combined into a single estimate. A more effective approach may be to estimate trends within sampling units or ecologically relevant collections of sampling units and summarize these results as percent of those with positive, negative, stable, or unknown trends (e.g., see Rieman et al. 2001). Proper specification of temporal units also is important in data analysis because procedures for modeling trend have minimum sample size (number of temporal observations) requirements for their use. Analyses will be limited to descriptive approaches until a requisite number of observations are available to reliably estimate trend.

7.1.1 Descriptive Analysis

Various descriptive statistics (e.g., means and standard deviations) and graphs will be generated frequently to provide information on status of a given vital sign. The frequency of analysis will depend on the vital sign and metric (Table 7-1). Graphical methods may include, but are not limited to, bar charts, scatter plots, and maps for viewing data on spatial distributions.

7.1.2 Trend Analysis

Observations recorded from the same area or individual over time are called repeated measures data. Within a population monitoring context, these data often have two components of total variance: 1) process variance, which includes spatial and temporal variances; and 2) sampling variance, which arises from measuring only a portion of the population or quantity of interest (Thompson et al. 1998). A key to increasing the ability to detect a trend of a specified size is to remove the sampling variance from the total variance so that only the temporal variance remains. Moreover, because repeated measures data are not independent, the correlation or covariance structure of the observations must be properly modeled to avoid bias. Consequently, we will use empirical Bayes models (also known as random effects or hierarchical linear/nonlinear models; Ver Hoef 1996, Clark 2005) to estimate trends. These models allow specification of different covariance structures, removal of the estimated sampling variance component, and incorporation of additional variables thought to influence trends in the response variable (e.g., abundance). When appropriate, we will build a candidate set of trend models that includes variables thought to most influence a given vital sign metric, use information-theoretic approaches to choose the best-fitting covariance structure and model, and, if necessary, model average over the candidate models (see Burnham and Anderson 2002). Ver Hoef (1996) and Ver Hoef and Frost (2003) used empirical Bayes models to estimate trends in abundance of harbor seals (*Phoca vitulina*), whereas Link et al. (2002) employed Markov Chain Monte Carlo methods with empirical Bayes models to fit bird population data.

Table 7-1 Summary of analytical techniques and responsibilities for analyzing data collected for SWAN vital signs. Lead contacts (program managers) work in collaboration with the SWAN biometrician on data analysis and interpretation. Trend analyses will be based on empirical Bayes models.

SWAN Project	Vital Sign and Protocol	Analysis	SWAN Lead Contact
Weather and Climate	Visibility and Particulate Matter	Annually summarize atmospheric/particulate data received from IMPROVE sites. Estimate trends in existing atmospheric/particulate data and every 5 years thereafter.	Physical Scientist
	Weather and Climate	Annually summarize data from weather stations. Estimate trends after 5 years of weather data are collected and every 5 years thereafter.	Physical Scientist
Landscape Dynamics and Terrestrial Vegetation	Glacier Extent	Document decadal change in glacier extent from satellite imagery.	Physical Scientist
	Volcanic and Earthquake Activity	Document important episodes of activity as they occur.	Physical Scientist
	Invasive/Exotic Species	Annually document and map occurrences of invasive species.	Botanist
	Insect Outbreaks	Annually document and map occurrences of new native and nonnative insect outbreaks. Estimate rates of expansion over 1-, 5-, and 10-year intervals.	Botanist
	Sensitive Vegetation Communities	Prepare summary statistics on species richness, species diversity, relative cover, and density of trees/shrubs every 3–5 years for first 10 years, and every 7–10 years thereafter.	Botanist
	Vegetation Composition and Structure	Prepare summary statistics on landscape-level vegetation change using satellite images taken at 5–10 year intervals. Summarize data on species richness, species diversity, relative cover, and density of trees/shrubs every 3–5 years for the first 10 years, and every 7–10 years thereafter.	Botanist
	Land Cover/Land Use	Map land cover change using satellite imagery every 5–10 years. Prepare summary statistics of changes in cover.	Botanist & Landscape Ecologist

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Table 7-1 (continued)

SWAN Project	Vital Sign and Protocol	Analysis	SWAN Lead Contact
Landscape Dynamics and Terrestrial Vegetation *(cont'd)*	Landscape Processes	Annually document dates of onset, dates of break-up, duration, and extent of ice cover on lakes; timing, extent, and location of snow cover; timing and extent of sediment plumes in large lakes and rivers; and onset, duration, and relative biomass of vegetation productivity. Estimate trends in these data every 10 years.	Landscape Ecologist
Marine Nearshore	Geomorphic Coastal Change	Summarize coastal shoreline change decadally. Estimate trends in shoreline position and substrate type every 10–12 years.	Coastal Ecologist
	Marine Water Chemistry	Summarize water chemistry data as available. Estimate trends every 5 years.	Coastal Ecologist
	Kelp and Eelgrass	Annually summarize data on abundance, distribution, and composition. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	Marine Intertidal Invertebrates	Annually summarize data on species richness, size distribution of limpets, abundances of littleneck clams, and contaminant levels in mussels. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	Black Oystercatcher	Annually summarize relative density of nests. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	Seabirds	Annually summarize abundance. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	River Otter (Coastal)	Annually summarize abundance and distribution data. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist
	Sea Otter	Annually summarize abundance and age-specific survival. Estimate trends after 10 years of data and every 5 years thereafter.	Coastal Ecologist

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Table 7-1 (continued)

SWAN Project	Vital Sign and Protocol	Analysis	SWAN Lead Contact
Marine Nearshore *(cont'd)*	Harbor Seal	Summarize abundance and distribution of haul-outs every 5 years. Estimate trends of existing data and every 5 years thereafter.	Coastal Ecologist
Lakes, Rivers, and Fish	Surface Hydrology	Annually summarize data on magnitude and timing of peak river discharge and lake-level change. Estimates trends every 5 years.	Aquatic Ecologist
	Freshwater Chemistry	Summarize water chemistry data as available. Estimate trends every 5 years.	Aquatic Ecologist
	Resident Lake Fish	Summarize data on species richness, species occurrence, and biocontaminant levels every 3–5 years. Estimate trends after 10 years and every 5 years thereafter.	Aquatic Ecologist
	Salmon	Annually summarize data on spawner abundance, distribution, timing of spawning, and freshwater residence times. Estimate trends from existing data and every 5 years thereafter.	Aquatic Ecologist
Terrestrial Animals	Bald Eagle	Summarize data on nest occupancy and distribution every 1-5 years. Estimate trends every 5 years.	Wildlife Biologist/ Biometrician
	Brown Bear	Summarize data on abundance and distribution every 5-10 years. Estimate trends after 20 years of data and every 10 years thereafter.	Wildlife Biologist/ Biometrician
	Wolf	Summarize data on abundance and distribution every 3–5 years. Estimate trends after 10 years of data and every 10 years thereafter.	Wildlife Biologist/ Biometrician
	Wolverine	Summarize data on abundance and distribution every 3–5 years. Estimate trends after 10 years of data and every 10 years thereafter.	Wildlife Biologist/ Biometrician

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Table 7-1 (continued)

SWAN Project	Vital Sign and Protocol	Analysis	SWAN Lead Contact
Terrestrial Animals *(cont'd)*	Moose	Summarize data on abundance, distribution, and sex-age composition every 3–5 years. Estimate trends after 10 years of data and every 10 years thereafter.	Wildlife Biologist/ Biometrician
	Caribou	Annually summarize data on abundance, distribution, and productivity. Estimate trends from existing data and every 5 years thereafter.	Wildlife Biologist/ Biometrician
Human Activities	Resource Harvest for Subsistence and Sport	Annually summarize harvest and subsistence data. Estimate trends from existing data and every 3–5 years thereafter.	Wildlife Biologist/ Biometrician
	Visitor Use	Annually summarize data on visitor use. Estimate trends from existing data and every 3–5 years thereafter.	Wildlife Biologist/ Biometrician

Due to the inherent variability of ecological and environmental systems, obtaining a precise estimator of trend often requires many observations. Based on a linear regression model, Urquhart et al. (1998) recommended a minimum of 10–15 sample years to detect even a moderate trend in U.S. Environmental Protection Agency water quality data. Therefore, even if trend analyses are conducted at frequent intervals, the ability to detect a trend will be low early in the process of data collection.

7.1.3 Linking Analyses to Decisionmaking

Lee and Bradshaw (1998) contended that the primary role of monitoring is to inform decisionmaking. They suggested that monitoring functioned best when it: (i) provided accurate estimates of trend of the environmental attribute(s) or natural resource(s) of interest; (ii) ensured that management decisions are implemented correctly; and (iii) provided insight into natural systems. They recommended use of Bayesian belief networks (BBNs) to link these goals within a single probabilistic framework. A BBN is a graphical model using geometric shapes (variables) and arrows (direction of causal influence) to depict the causal relationship among variables and to an outcome (e.g., population trend; Marcot et al. 2001). This model can use both empirical data and expert judgment in a probabilistic manner (see Appendix IV for further details; see also Marcot et al. 2001, Rieman et al. 2001). BBNs offer a transparent and quantitative framework to link monitoring data to decisions regarding the current "state of the park" for different vital signs.

Figure 7-1 shows an example BBN plus decision node for population trend of sockeye salmon (*Oncorhynchus nerka*) escapement in the Lake Clark watershed (see Table 7-2 for details). An important step is to build a population dynamics model to simulate adult recruitment. Simulation model outputs and existing data can help parameterize the network. The parametrized network then can be used to identify the most likely trend category (increasing, stable, or decreasing), with associated level of uncertainty, as well as to evaluate different harvest strategies. The network can be easily updated over time as more trend data are collected.

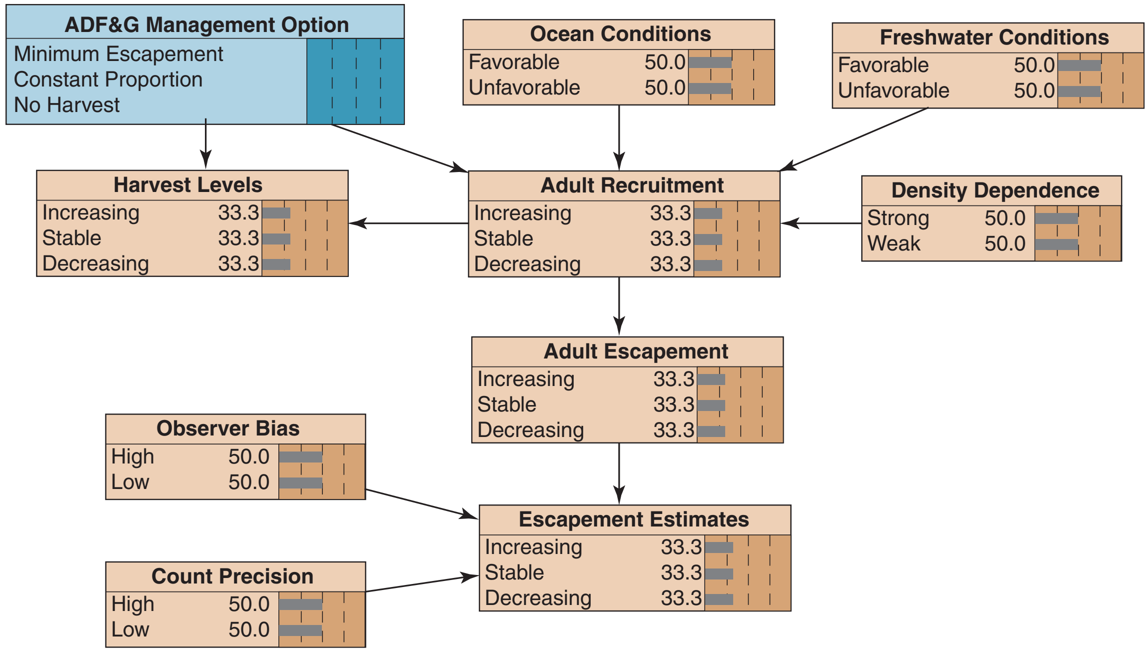

Figure 7-1 *An example belief network plus decision node (ADF&G Management Option) to illustrate information used to estimate the most likely trend (with measure of uncertainty) in sockeye salmon escapement in the Lake Clark watershed (example network provided by D. C. Lee).*

7.2 Reporting

As described in Section 1.2, the broad-based, scientifically sound information obtained through vital signs monitoring has multiple applications for management decisionmaking, research, education, and promoting public understanding of park resources. How information is communicated, archived, and made available largely determines a monitoring program's efficacy, reputation for reliability, and image among critics, peers, and advocates (Davis 2005).

> *"State of the art science," no matter how much it is admired by academics, should often be dispensed with in favor of science that can be understood and believed by the people who will use it.*
>
> *(N. Thompson Hobbs)*

The primary audience for the results of vital signs monitoring is park management: superintendents, park resource chiefs, and other managers who require natural resource data to make and defend management decisions. However, other key audiences for monitoring results include park planners, interpreters, researchers and other scientific collaborators, the general public, and Congress and the Office of Management and Budget. To be most effective, monitoring data must be analyzed, interpreted, and provided at regular intervals to each of these audiences in a format they can use, which means that the same information needs to be packaged and distributed in several different formats. Monitoring reports will undergo peer review by locally involved specialists (other SWAN scientists), and external peer review by scientists from other federal, state, or private agencies.

The content and amount of detail included in the various products of the monitoring program will differ depending on the intended audience for each report (Figure 7-2). At the Network level, park managers and natural resource staff and collaborators need to have available the detailed, complex scientific data relevant to the park's issues and resources. At the national level, however, a different scale of analysis and reporting is needed to be most effective. To report on the status and trends in the condition of natural resources in the National Park System, the NPS is developing a Natural Resource Scorecard that will involve the integration and evaluation by experts of detailed scientific data for each park and resource category. For effective communication, the overall assessment of resource status and trends (the "highly aggregated indices" zone at the top of the information pyramid shown in Figure 7-2) will be presented

Table 7-2 Description of nodes within the example belief network (D. C. Lee, personal communication) portrayed in Figure 7-1.

Node Label	Node Description
Harvest Policy	Decision node. ADF&G has regulatory authority over commercial fishing harvest of sockeye salmon in Bristol Bay and currently follows a minimum escapement harvest policy. Belief network can evaluate relative impacts of different harvest policies on sockeye salmon escapement.
Harvest Levels	Commercial fishing harvest of returning adult sockeye salmon could potentially have an adverse impact on run sizes during years of low runs. ADF&G maintains annual commercial catch statistics of returning adult sockeye salmon in Bristol Bay.
Ocean Conditions	Survival of sockeye salmon during ocean residence as related to the Pacific Decadal Oscillation (Mantua et al. 1997) and other factors. Use range of estimates from other studies (e.g., Beamish et al. 2004).
Freshwater Conditions	Effect of spawning/rearing freshwater conditions on egg-to-smolt survival, pre-spawning survival, and spawning success. Use data collected for Lake Clark from SWAN I&M program's proposed water quality monitoring protocol.
Density Dependence	Level of constraint imposed on population numbers by habitat capacity, i.e., increased escapement leads to fewer recruits and vice versa.
Adult Recruitment	Trend in number of adults surviving to adulthood prior to spawning.
Adult Escapement	Actual trend in number of adult sockeye salmon returning to spawn that avoid capture by commercial, recreational, and subsistence fishing.
Escapement Estimates	Estimated trend in number of adult sockeye salmon returning to spawn that avoid capture by commercial, recreational, and subsistence fishing. Trend estimated from tower counts along the Newhalen River.
Observer Bias	Systematic error in tower counts of adult salmon returning to spawn on the Newhalen River. Key variables influencing counting conditions (e.g., cloud cover, wind velocity, turbidity) are recorded daily for tower counts on the Newhalen River. Also, use published estimates of bias for similar species in other studies (e.g., O'Connell 2003).
Count Precision	Degree of spread in repeated tower counts of adult salmon returning to spawn on the Newhalen River.

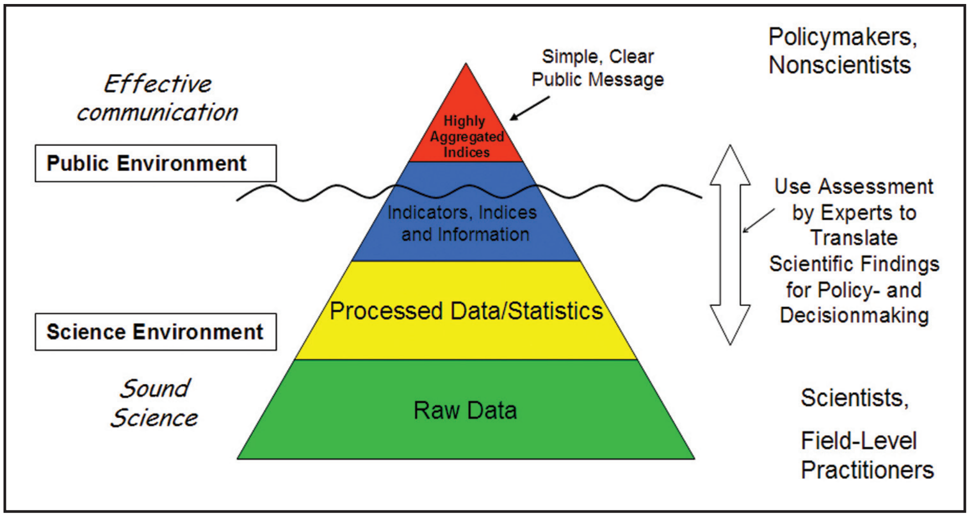

Figure 7-2 *The information pyramid. The amount of detail and scale of analysis of scientific data will differ depending on the intended audience for the various reports and presentations. National-level reporting to the American public and to Congress will involve assessments by experts using simple graphical messages, but the results will be supported by often complex data that are available at the park and Network level. (Taken from presentation by S. Fancy, NPS, 2/2005).*

using a simple, clear public message, but the results will be supported by the large amount of detailed, complex scientific data and information depicted as the lower levels of the information pyramid.

We propose to meet the challenges of information reporting by communicating frequently and providing our results and products in a variety of formats (Table 7-3). Frequent communication will occur through scheduled annual reporting and informal meetings with park managers. Information will be reported in numerous formats using language that simultaneously fits within both scientists' and nonscientists' frames of reference, such that progress and findings are technically accurate and understandable. Collaborative learning will occur in forums such as the investigators report to the technical committee and informal park meetings that are designed to provide immediate access to new information and develop a shared understanding of ecological change and how it relates to resource management issues. We anticipate that reporting procedures will evolve with the monitoring program and adapt to changing communication technology.

7.2.1 Newsletters

Newsletters will provide contemporary information, including network news, alerts, recent discoveries, or changes in staff, among other information. Newsletters will be two to four pages and published annually or semiannually. They will be published online and circulated to the parks in hard copy so they are easily accessible. Newsletters will be archived on the network web page to provide an easily accessed record of network activity.

7.2.2 Annual Park-Specific Status Report

Park vital sign status reports will annually summarize information from the vital signs program. These reports will be park specific and provide clear linkage to how the vital signs data addresses specific network goals. Reporting will coincide with park managers' needs to integrate the information into park reporting requirements. For example, if parks are reporting on GPRA goals in November–December, then SWAN will provide summaries of vital signs that address GPRA goals in September–October.

7.2.3 Scientific Posters and Peer-Reviewed Literature

Monitoring project leaders and cooperators will develop and present posters at meetings, workshops, and conferences. SWAN will provide copies of these posters to parks for them to display. The distillation of network projects into posters or other easily interpreted formats will be included as products in cooperative agreements. Peer-reviewed literature will be a primary means of communicating information to other scientists as well as park biologists and managers.

7.2.4 Personal Contact

Personal relationships with park managers through face-to face-interactions will be an important element of reporting. These meetings will facilitate strong relationships with park staff and integrate monitoring results into park resource management. These meetings may occur during park seasonal training periods to present the I&M program to incoming seasonal staff of all divisions; through park-specific presentations or “SWAN Road shows” where network staff present park specific information to each park; and through biennial symposiums where scientists present their research results to network park staff and the public.

7.2.5 Tracking How I&M Information is Used

As an element of reporting, SWAN will track how network staff are used to assist with park management issues and how vital signs monitoring data are used in park planning and resource protection. This process will be used to measure the effectiveness of the long-term monitoring program in meeting objectives and improving science-based park management.

7.3 Interpretation and Outreach

The goal of the SWAN education and interpretation program is to strengthen the understanding and appreciation of science in our national parks. This goal capitalizes on the ability of SWAN to link education, research, stewardship, and resource management, into meaningful messages about the status and trends of park resources. Most interpretation and outreach will be accomplished though park-based interpreters, Ocean Alaska Science and Learning Center-Seward (OASLC), and Islands and Ocean Visitor Center-Homer. An education coordinator based at the OASLC will oversee the program and work with project leaders to identify potential products.

Information will be disseminated to the public by:

- Web sites and posters
- Participating in public workshops, conferences, and meetings
- Articles in journals/newsletters of local organizations
- Local educational and outreach programs
- News releases to local media
- Public lecture series

Table 7-3 Summary of various reporting outlets for information produced from the SWAN vital signs monitoring program.

Type of Report	Purpose of Report	Primary Audience	Frequency	Person(s) Responsible
Annual Administrative Report and Work Plan	Program account for funds and FTEs expended; summary of accomplishments, highlights, and plans for upcoming year of the monitoring program	Board of Directors, Technical Committee, Regional and Washington Office Staff	Annual	Network Coordinator and Staff
Annual Technical Reports for a Protocol or Project	Present comprehensive data results, including data tables, discussions of results, and charts, and the Status and Trends of a resource. Document changes in monitoring protocols. Inform park and Network staff.	Park Resource Managers, Network Staff, External Scientists	Annual	Network Coordinator and Staff
Annual Report on "State of the SWAN Parks" (Report and Web-based information)	Summarize for managers and interested members of the public some of the major, current findings of the monitoring program. This annual report is intended to be a standing report that SWAN staff adds to, edits or changes once each year.	Superintendents, Park Resource Managers, Network Staff, External Scientists, Public	Annual	Network Coordinator and Staff
Investigators Report to the Technical Committee	Project investigators update park and Network staff on progress, highlights, preliminary findings, and future plans. Provides an opportunity for investigators to share information and plans.	Superintendents, Park Resource Managers, Network Staff, Cooperators	Biennial	Network Coordinator and Staff
Scientific Posters and Peer Reviewed Literature	Convey significant findings to professional audiences.	Park Staff, Agency, External Scientists, Public	Infrequent	Network Staff and Cooperators
DVD's and Glossy Brochures	Information and educational products that are integrated into park interpretive programs	Superintendents, Park Staff, Visitors, General Public	Infrequent	Network Outreach Staff
Informal Park Meetings	In-park "open house" meeting where Network staff provide an update and answer questions.	Park Staff From All Divisions	Annual	Network Staff and Host Park I&M Leader